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PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Commissioner
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United States Patent and Trademark Office, PCT
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Arlington, VA 22202
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 24 January 2002 (24.01.02)	
International application No. PCT/GB01/01182	**Applicant's or agent's file reference** P/70038/SF
International filing date (day/month/year) 19 March 2001 (19.03.01)	**Priority date** (day/month/year) 18 March 2000 (18.03.00)
Applicant OATES, Donald, Colin, Murray	

1. The designated Office is hereby notified of its election made:

   [X] in the demand filed with the International Preliminary Examining Authority on:

   11 October 2001 (11.10.01)

   [ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was
   [ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland** Facsimile No.: (41-22) 740.14.35	Authorized officer Pascal Piriou Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREATY

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NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92bis.1 and Administrative Instructions, Section 422)

To:

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Date of mailing (day/month/year) 24 janvier 2002 (24.01.02)	
Applicant's or agent's file reference P/70038/SF	**IMPORTANT NOTIFICATION**
International application No. PCT/GB01/01182	**International filing date** (day/month/year) 19 mars 2001 (19.03.01)

1. The following indications appeared on record concerning:
☐ the applicant ☐ the inventor ☒ the agent ☐ the common representative

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2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:
☐ the person ☐ the name ☒ the address ☐ the nationality ☐ the residence

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3. Further observations, if necessary:
The new address on the demand has been considered as a change under Rule 92bis. In case of disagreement the International Bureau should be notified immediately.

4. A copy of this notification has been sent to:
☒ the receiving Office
☐ the International Searching Authority
☒ the International Preliminary Examining Authority
☐ the designated Offices concerned
☒ the elected Offices concerned
☐ other:

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland** Facsimile No.: (41-22) 740.14.35	Authorized officer Pascal Piriou Telephone No.: (41-22) 338.83.38

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The Patent Office

Application No:	GB 9625305.9	**Examiner:**	Matthew Nelson
Claims searched:	1-11	**Date of search:**	4 March 1997

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): G3U (UAE2)

Int Cl (Ed.6): G05F (1/14, 1/147), H02H (7/055), H02P (13/06)

Other: Online:- WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	EP 0495590 A2	(HITACHI). See page 3; lines 19-24, page 5 & fig 5.	
A	US 5136233	(DUEKER et al). See col 4 line 62 - col 5 line 4.	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

The Patent Office

Application No:	GB 9625305.9	**Examiner:**	Matthew Nelson
Claims searched:	27	**Date of search:**	20 June 1997

Patents Act 1977
Further Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): G3U (UEG)

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Other: Online:- WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
Y	US 5541498	(BECKWITH). See in particular col 20, lines 8-41.	27
Y	US 5402057	(D'AQUILA). See col 5, lines 19-25 & figure 4.	27
Y	US 4353024	(GYUGYI). See abstract & figure 7.	27

101

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

The Patent Office

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INVESTOR IN PEOPLE

Application No:	GB 0006513.6	**Examiner:**	Brian Ede
Claims searched:	1-17	**Date of search:**	21 July 2000

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Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

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Int Cl (Ed.7): H02M 5/22 5/257 5/293 7/48 7/505 7/515 7/521 7/53 7/537 7/5387

Other: Online: EPODOC, JAPIO, WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	GB 2301239 A	(S. SOAR and S. R. GREENWOOD) see Fig 10	-
A	GB 1153440	(SOC. GENERALE DE CONSTRUCTIONS ELECTRIQUES ET MECANIQUES ALSTHOM) see Figs 1, 6 and 9	-
A	GB 1042269	(WESTINGHOUSE ELECTRIC) see Fig 2	-
X	JP 550008278 A	(MEIDENSHA ELECTRIC) 21.01.98 (see PAJ vol 004036)	1, 3 and 10-15
X	JP 110055954 A	(FUJI ELECTRIC) 26.02.99 (see WPI Abstract Accession No 1999-222002)	1, 3, 10-13 and 15
X	JP 100042576 A	(MATSUSHITA) 13.02.98 (see WPI Abstract Accession No 1998-186602	1, 3 10-13 and 15

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Application No: GB 0006514.4
Claims searched: 1 to 19

Examiner: Nik Dowell
Date of search: 5 September 2000

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UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

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Other: Online : WPI, EPODOC, PAJ

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	GB 2 320 109 A (Beckwith)	-
A	US 5 895 979 A (Kojovic)	-
A	US 5 008 560 A (Kieren et al.)	-

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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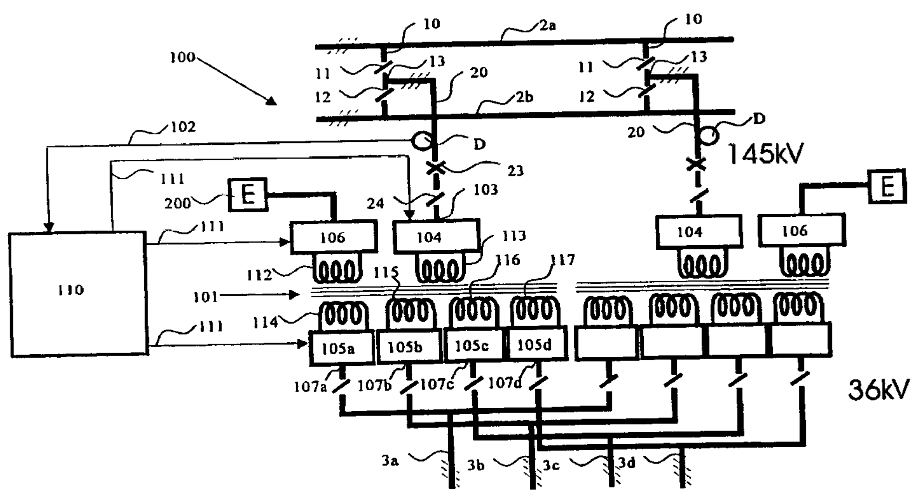
(54) Title: AN IMPROVED ELECTRICAL SUBSTATION



(57) Abstract: A substation (100) is disclosed for use in a power transmission and distribution network. The substation comprises a single phase isolating high frequency transformer (101) having at least one input winding (112, 113) and at least one output winding (114-117) with corresponding input (104) and output (105) solid state switching networks. Each input solid state switching network (104) comprises a plurality of semiconductor switching devices which receive an input waveform from the transmission network and output a high frequency waveform to the primary winding of the transformer. Likewise, each output solid state switching network (105a-105d) comprises a plurality of semiconductor switching devices receiving a high frequency waveform from the secondary winding (114-117) of the transformer and outputting an output frequency waveform from the substation. A control means (110) is adapted to control the operation of the switching devices of the input and output switching networks (104, 105) to generate the output waveform from the input waveform.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

AN IMPROVED ELECTRICAL SUBSTATION

This invention relates to improvements in electrical substations, and in particular to a substation for use in power transmission and distribution systems.

Both heavy industry and domestic users consume increasingly large amounts of electricity. As the electricity is generated in central locations at power stations, there is thus a need for both transmission and distribution of electrical power over large distances.

Most electrical power transmission uses alternating AC voltages and currents due to the ease with which an alternating supply can be generated and then converted from one voltage level to another using transformers. DC transmission systems are also used in some cases, especially where power is to be transmitted over very large distances. An example of such a DC system is the link between the United Kingdom and France which operates at around 500k volts.

For efficiency, the voltages at which power is transmitted in an AC network are necessarily very high. For overhead power cables in the United Kingdom, transmission at 128k volts, 160k volts, 220k volts and 280k volts is common, but different countries use different voltages for administration and historical reasons. Generally transmission occurs at around 150k volts or more, with distribution below 150k volts. As this is considerably higher than the domestic voltage used, typically 400 volts at three phase, then it is necessary to convert the high voltage to a lower voltage when tapping off power from the transmission line.

Power is taken off the main transmission lines by substations which fall into two main categories: transformer sub-stations and switching sub-stations.

The transformer sub-station's role is to convert between the very high voltages present on the transmission network and intermediate levels suitable for electricity generation and distribution to a specific area such as an industrial or housing development. For example, in the United Kingdom substations may typically be required to convert a 220k volt input into a 60k volt output suitable for an urban supply. They are typically located outside of urban areas and act as the first tap onto the network transmission.

The role of the switching substation is simply to direct power from one part of a distribution network to another. Typically this would be to take a tap from a ring distribution network. Switching sub-stations do not generally either step-up or step-down the voltage.

Of course, substations may serve other roles, such as the transmission and distribution of power to a railway network. In general, however, a common feature to all substations is that they receive an input at a first voltage and provide an output at a second voltage. The two voltages are usually different in magnitude, but could be of the same magnitude but different in phase due to transmission delays.

At present, because of the high power levels in transmission and distribution systems the use of AC power is most prevalent as it allows substations to be constructed around a simple transformer to convert voltages from one level to another. These are protected by circuit breakers so that the transformer can be isolated in the event of a fault and to allow repairs to be carried out. To ensure continuity of supply, two transformers are usually provided in parallel, each being connected to the network through circuit breakers so that one can be completely isolated whilst allowing power to be transmitted through the remaining transformer.

To fine tune the output voltage from the transformer one or more tap changers are typically provided. In use the output voltage is periodically monitored and the tap changer moved to add in or remove one or more turns of the transformer winding until the correct output voltage is obtained. Other than this, adjustment in situ is very limited.

As well as their limited flexibility a further disadvantage of transformer based substations is that they are extremely bulky and quite crude in their operation.

A problem specific to transmission networks employing overhead lines is that the amount of power which can be passed down the line will depend on the weather conditions as well as the condition of the line (for instance during maintenance). In hot weather the cables will expand and droop towards the ground. This reduces the power that can be passed down the line. Also, more power can be passed down the line on a windy day than on a calm day as the wind helps to dissipate heat produced by the cables. Known substations based on passive transformers require additional circuits upstream to compensate for such changes if power flow along the lines is to be optimised.

For example, one device which can be used to optimise power flow comprises a VAR Compensator which introduces a variable reactance to the line to balance changes in line inductance. Again, this adds to the complexity and the cost of the system.

An object of the present invention is to provide a substation for use in a transmission and distribution network which overcomes, at least partially, some of the problems of known substations comprising passive transformers.

In accordance with a first aspect, the invention provides a substation for use in a power transmission and distribution network comprising:

a single phase isolating high frequency transformer having at least one input winding and at least one output winding;

an input solid state high frequency switching network comprising a plurality of semiconductor switching devices, the input switching network defining at least one input node for receiving an input power waveform from the transmission network and at least one output node connected to the primary winding of the transformer;

at least one output solid state high frequency switching network comprising a plurality of semiconductor switching devices, the output switching network being connected to the secondary winding of the transformer and defining at least one output node from which an output power waveform can be taken from the substation; and

control means adapted to control the operation of the switching devices of the input and output switching networks to generate the output waveform at the output node from the input waveform applied to the input node.

The invention thus replaces the known passive transformer substations with a semiconductor based system in which a control means operates suitable devices to produce an output waveform from an input waveform.

Note that "high frequency" in the context of the switching circuitry and the transformers used in the present invention means high relative to normal supply frequencies such as 50Hz, e.g., frequencies of about 1kHz and above.

The system is active in that the control of the switches is dependent upon the power condition in the input line as measured by the current and/or voltage applied to the input node.

Preferably, the substation is adapted to operate over input voltages greater than 150k volts, or greater than 100k volts or perhaps greater than 10k volts.

The control means may include measurement means adapted to monitor the condition of the input voltage and modify or generate control signals for the switching devices dependent upon the measured value or values.

The use of such an active control system provides considerable advantages over the prior art. Firstly, it allows much greater control over the output voltage produced. In a passive transformer system, the output voltage waveform is fixed relative to the input by the turns ratio of the transformer. In the substation of the invention the output is no longer dependant in such a limiting way on the construction of the transformer. Indeed, a turns ratio of 1:1 could be used, the conversion being entirely dependant upon the operation of the switching devices.

The input switching device network may comprise a bridge circuit having at least one input node for each phase of the input supply. Typically, three input nodes are envisaged for a three phase distribution network. The input switching network may include a resonant element which forms a tank circuit, the switching circuit acting to maintain a flow of current in the tank circuit.

Preferably, the transformer comprises a single phase transformer. In a passive prior art system, the transformer must have a transformer phase for each input phase. Hence, for a three phase supply a three phase transformer would have been needed.

Where a single phase transformer is provided, the control means may be adapted to control the switching of the semiconductor switching devices so that a single substantially sinusoidal waveform is generated in the input side of the transformer whilst the semiconductor switching devices on the output side of

the transformer are operated to reconstruct one or more output waveforms of different phase from the transformer output.

In a most preferred arrangement, the control means is adapted to control the semiconductor switching devices so as to produce at least one output voltage waveform which is independent of the input voltage waveform. Thus, a clean output waveform could be produced from a noisy input waveform. This cannot be achieved using a passive transformer substation which would faithfully reproduce the input noise in the output waveform.

The semiconductor switching devices may be arranged in relation to the transformer so that in the event of a failure of one or more switching devices or of the transformer or of the control means then power is not transmitted across the transformer. This acts as a fail safe arrangement. In one construction, a fail safe mode could be achieved by forcing all the switching devices to the same state, isolating the input waveform from the transformer.

The control means may be adapted to control the semiconductor switching devices, at least of the input switching network, in such a way as to match the input impedance of the substation to the source impedance of the supply line. This maximises power transfer from the supply line, and effectively eliminates the need for a separate VAR compensator which would be needed to achieve the same result with a passive transformer based system.

The source impedance may be controlled in real time by modifying the switching state of one or more of the semiconductor switching devices under the control of the control means. Means may be provided to monitor the input (source) impedance and the control means may be responsive to this.

The control means may be adapted to control the semiconductor switching devices to generate an output waveform that differs in phase from the input waveform. This could be adapted to gradually alter the phase of the output over time, for instance to match the output waveform to the demands of a load.

In another refinement a limiting means may be provided which is adapted to reduce the output voltage produced if the current drain exceeds a preferential maximum level. This can be used to temporarily allow the voltage to dip if an excess load current is drawn. The limiting means may comprise means adapted to monitor the output current drawn by the load and means adapted to modify the control signal applied to the semiconductor switching devices to reduce the output voltage if the current exceeds a threshold value.

The degree of sophistication of the system can be varied to provide various limiting controls. In one arrangement the control signals may be modified in response to a measure of the rate of change of current drawn. This can allow the system to mimic the action of a fuse.

The provision of the solid state substation can be used to provide several novel arrangements of distribution network.

Thus, in accordance with a second aspect, the invention provides a transmission and distribution network comprising a transmission line for the transmission of electrical power from a generator, a substation in accordance with the first aspect operatively connected to the transmission line, and one or more distribution lines connected to the output of the substation for onward supply of power to a load.

By load we may mean a direct load such as a motor or furnace, or perhaps another substation or part of another network.

The load may comprise a second transmission line adapted to transmit alternating voltage from a generator, and the substation may be adapted so that the control means controls the switching of the switching devices to generate an output waveform for supply to the second network which is in phase with the phase of the voltage on the second network. Thus, two out of phase or even different frequency networks can be readily supply connected together to share power.

At least two substations may be connected in parallel between the supply line and the output load. This allows one substation to be removed from the network for repair as well as allowing the network to continue to function in the event that one substation fails.

A circuit breaker may be provided upstream of the or each substation. This allows the substation to be isolated from the transmission line.

The network may comprise a consumer electrical transmission and distribution network. The transmission line may supply voltage at say 145k volts or thereabouts, or perhaps 220k volts or more than 220k volts.

The load may operate at 36k volts, or perhaps 20k volts, or any value greater than either of these values.

Alternatively, the network may comprise a supply network for an electrical railway system.

There will now be described, by way of example only, embodiments of the present invention with reference to the accompanying drawings, in which:

Figure 1 is a schematic illustration of a prior art passive substation for use in a power transmission and distribution network;

Figure 2 is a schematic illustration of a substation in accordance with the invention for use in a supply network;

Figure 3 is a schematic illustration of one way of implementing the converters 104 in Figure 2; and

Figure 4 is a schematic illustration of one way of implementing the inverters 106 in Figure 2.

The substation 1 illustrated in Figure 1 of the accompanying drawings is connected between two three phase transmission lines 2a, 2b which carry 145k volt waveforms and four three phase output lines 3a,3b,3c,3d at 36k volts for onward distribution to a domestic supply network.

Looking at the left-hand side of Fig. 1, a spur line 10 connect the two input transmission lines 2a,2b together and includes two electrical isolators 11,12 which are provided between a centre tap 13 of the spur line and a respective transmission line. The isolators 11, 12 can both be opened (i.e. made non-conducting) to completely isolate the centre tap 13 from both transmission lines. Alternatively, one isolator can be closed (i.e., conducting) to connect the tap to one or other of the transmission lines 2a,2b.

The centre tap 13 provides a take off point for a supply line 20 to an input side of a three phase transformer 21. The output of the transformer, which is again three phase, is connected through a spur 22 to the four output lines 3a,3b,3c,3d.

A circuit breaker 23 and an electrical isolator 24 are connected in series between the transformer 21 and the centre tap 13 so that it can be isolated from the supply lines for repair or replacement.

Another circuit breaker 25 is provided downstream of the transformer 21 to isolate it from the output lines 3a,3b,3c,3d. Of course, in normal use the circuit breakers are closed to allow current to flow in the transformer windings.

Finally, each of the output lines 3a,3b,3c,3d is connected to the transformer 21 through a respective circuit breaker 26,27,28,29 for extra protection.

The whole assembly of spurs, centre tap, transformer and circuit breakers/isolators is duplicated as shown on the right hand side of Figure 1 to provide two parallel connected circuits. This is necessary to allow continuity of supply in the event that one of the transformers is shut down.

As shown, for a 145k volt supply with each transformer stepping the voltage down to 36k volts, the transformers typically need to be able to handle 60 - 90 MVA (i.e. Megawatts) of power. They are therefore extremely bulky.

An alternative substation, which is intended to replace that shown in Figure 1, can be constructed in accordance with the principles of the present invention. Such a substation 100 is illustrated in Figure 2 of the accompanying drawings. Note that connections carrying three-phase current are indicated by three thin parallel hatching lines.

The basic layout of the substation of Figure 2 is the same as for Figure 1 in so far as it includes two identical (left and right) transformer circuits. The main difference is that instead of a passive system employing a three phase step-down transformer, each transformer circuit now includes a single phase transformer 101 with associated high frequency switching circuitry, e.g., frequencies of about 1kHz and above. Only the left-hand half of the circuitry will be described hereinafter for clarity. Where possible, identical reference numerals to those used in Figure 1 will be employed.

The single phase transformer 101 has two input or primary windings 112,113, connected respectively to input switching circuits 106, 104, and four output or secondary windings 114,115,116,117, connected respectively to output switching circuits 105a to 105d, which in turn are connected to the output load lines 3a,3b,3c,3d. Several secondary windings with associated output switching circuits are utilised for reasons of increased reliability of the substation and enhanced flexibility of power supply management to the load(s). A supply line 20 to the transformer 101 from the transmission lines 2a,2b is connected to an input node 103 of input switching circuit 104. In practice, three input nodes 103 to switching circuit 104 are required for a three phase transmission line. In use, the input or primary windings 112 or 113 of transformer 101 are driven by the input switching circuits 106 or 104 which are controlled to produce the appropriate waveform in their associated winding. This waveform is then replicated in the output or secondary windings 114-117 and the output switching circuits 105a to 105d are controlled to produce a desired output waveform at their output nodes 107.

The input and output switching circuits 104, 105 and 106 each comprise a network of semiconductor switching devices, such as IGBT'S, connected to form a bridge.

Fig. 3 illustrates an example of a suitable switching network for the input switching circuit 104. It comprises a power converter in which semiconductor switches SW1 to SW6 form a reversible rectifier to allow bi-directional power to flow between the DC link voltage (V_{DC}) and the three phase 50Hz AC waveform. The operation of the switches is such that a variable mark:space square wave is generated using conventional high frequency pulse width modulation (PWM) techniques, with the voltage levels defined by the DC link voltage. The average of this defines a voltage that is applied to one end of the

AC filter inductor (L1 - L3). Since the rectifier circuit is only referenced to the supply the average of the three voltages produced by the PWM action has to equal the average of the three phase supply. The voltages produced by the PWM action will be a three phase 50Hz sine wave of equal frequency and variable magnitude and phase relative to the AC supply, which are controlled to define the magnitude and phase of the current in the inductors. Controlling whether the PWM generated voltage leads or lags the supply voltage controls whether power is passed to the supply or drawn from it respectively. Similarly, the magnitude of the PWM generated voltage relative to the supply voltage determines the degree of power factor correction that is applied. The control of such converters is standard practice and for a more detailed study of how this can be carried out, reference can be made to papers such as: Schauder, Mehta, "Vector analysis and control of advanced static VAR compensators", IEE Proceedings Part C, Vol 140, No 4, July 1993; and Barras, Cade, "PWM rectifier using indirect voltage sensing", IEE Proceedings, Power Applications, Vol 146, No 5, September 1999. The value of the filter capacitor, C1, must be such as to minimise 100Hz voltage harmonic components in the DC link voltage arising from out of balance voltages in the AC supply voltage.

Semiconductor switches SW7 to SW10 form a full, four-quadrant bridge circuit that will allow bi-directional power flow across the high frequency transformer. To source power into the high frequency transformer in parallel with other sources (when they are present) requires that some reactance is present in series with the transformer. The transformer has a degree of self-inductance that may be sufficient so a separate component may not be required. The two pairs of switches SW_7-SW_{10} each use high frequency PWM to generate a square wave, displaced in time. The degree of displacement between the two square waves defines the magnitude of the waveform to be applied to the transformer. Where there are several power sources applying power to the transformer, the flow of power is determined by the voltage applied to the series inductance L_4, defined

by the phase relationship between the transformer voltage and the voltage derived by the bridge switching. This operation is similar to that described in Kheraluwala, Gascoigne, Divan, Baumann, "Performance characterisation of a high-power dual active bridge DC-to-DC converter". IEEE Transactions on Industry Applications, Vol. 28, No 6, Nov/Dec 1992, to which the reader is directed for details. In this reference, converters are placed across opposite sides of a transformer and phase delay between the converters is used to improve the operation of the switching. Other forms of power converter that may be used in the present invention are given in Pressman, "Switching Power Supply Design", McGraw Hill, ISBN 0-07-052236-7, 1998.

Alternatively, and preferably, the switching circuit 104 can be a resonant matrix converter, as shown and described with reference to Figure 2 of our co-pending International patent application claiming priority from British patent application number GB0006513.6, filed 18th March 2000. The example given therein is for a motor power supply, but the principle is equally applicable to the present case.

Referring again to Figure 2 of the present application, the three phase output on lines 3a to 3d is reconstructed from the single phase transformer waveform using pulse width modulation to control solid state switching networks in the output switching circuits 105a to 105d so as to “reconstruct” a waveform of the desired phase and frequency. Each output switching circuit 105 may be a mirror image of input switching circuit 104, and so need not be further described, except that it will have different voltage and current ratings, as appropriate. Known smoothing circuitry is also provided to refine the shape of the output waveforms.

As indicated at E in Figure 2, it is proposed in this embodiment of the invention to provide a means of back-up DC energy storage or supply. The most common and reliable forms of DC energy storage used in power electronics are either

based on capacitors for small and medium amounts of energy or batteries for large amounts of energy. However, fuel cells could also be used as a backup supply. It is convenient to operate such a back-up energy system through the secondary winding 112 of the single phase transformer 101 and it will be necessary to regulate the current inflow and outflow from the storage device E; hence, it is interfaced to the transformer through a switching circuit 106 comprising a DC to AC high frequency inverter, for example, as shown and described with reference to Fig. 1 of our co-pending International patent application claiming priority from British patent application number GB0006513.6, filed 18th March 2000.

Alternatively, input switching circuit 106 may be implemented as shown in Figure 4, which shows a conventional full, four-quadrant bridge circuit being used to allow bi-directional power flow between the transformer and the energy store E, shown in the figure as a battery. This circuit will not be further described because it is operated in an identical manner to the full four-quadrant bridge circuit shown and described with reference to Fig. 3.

Returning to Figure 2, the semiconductor switches in the input and output switching circuits 104, 105, 106 are controlled by control signals on control lines 111 generated from a control unit 110. This unit comprises a central processing unit which generates control signals. The processing unit constructs appropriate control signals dependant upon instructions from a suitable control program and the condition of the power supply in lines 2a and 2b, as represented by signals on line 102 from a measurement device D which measures the current and voltage flowing along the input line 20 to the input switching circuit 104. For example, device D may comprise voltage and current transformers, which are well known in themselves.

The control program for controller 110 may use known PWM techniques, such as natural sampling or sliding mode control, to regulate the current and/or voltage in the output lines 3a-3d so as to assist network power stability in cases where there are other power sources feeding into the same local power network as the transformer 101. It should be noted that synchronous machines used for power generation inherently operate in synchronism with other generation sources. For any phase disturbance to the machine or the power system to which it is connected there is a strong force to restore the state of equilibrium, resisted by the inertia of the machine. As power networks become large and complex the nature of this restoring force can be compromised due to the manner in which the different generators and loads interact. For the present invention, the restoring force and inertia are absent and phase lock is controlled electronically, so it will not adversely affect the dynamic stability of the power transmission or distribution system to which it is connected.

As an example of use of the energy store E, suppose - as sometimes happens - there is a short break (of up to say one half cycle) in the supply voltage waveform on lines 2a and 2b. When this occurs, it will be signalled to the controller 110 by the measurement device D and the input switching device 104 can be switched by appropriate control signals so as not to generate a waveform in the associated primary winding 113, the output switching device 106 also being switched at the same time to provide a short burst of power from store E - this being a capacitor bank - to fill in the missing part of the cycle. When normal operation is resumed, this capacitor bank can be recharged by reverse operation of the of the switching device 106 using energy taken from the supply lines 2a, 2b via line 20 and primary winding 113.

By providing input and output solid state high frequency switching circuits in combination with a single phase high frequency transformer, considerable

operational benefits are achieved. Some of the advantageous features are set out below.

(1) Matched Sink Impedance control

The input impedance of a converter circuit such as input switching circuit 104 is a measure of how the input current drawn by the converter compares with the voltage applied to the converter.. As previously mentioned, the 3 phase voltages and currents may each be represented by a technique known as "Sliding mode control", in which the magnitudes of each of the three phases are mapped into single rotating vectors in two-dimensional space. It should be noted that a third number is generated, which for a balanced 3-phase system should be zero. If the vectors for the voltage and current overlay each other, the input impedance is resistive, if the current is in advance of the voltage then the input impedance may be regarded as a parallel RC (resistance-capacitance) network. There will be a natural tendency for the current to lag the voltage due to the inductance of the transmission system. This will reduce the terminal voltage at the converter and so a direct method of defining the current relationship to the source voltage to compensate for this can reduce transmission losses. This can be readily achieved by the present invention by selecting appropriate control signals for the switching devices.

Considering the circuit shown in Fig. 2 of our previously mentioned copending application, in which the switching devices are connected in a bridge, the requirement is to control the switching of the bridge circuits so as to regulate the currents in the input inductances in a defined manner. Considering a 3-phase AC system, with a three arm bridge, there are eight permitted combinations of switching for the devices for each half cycle of the inverter. The switching state may be changed as zero voltage is reached on each half cycle of the resonant circuit both to maintain the resonant operation of the "tank circuit" and to regulate the current in the inductors (note that the tank circuit is the resonant

LC network across the output of the resonant matrix converter shown in Fig. 2 of our previously mentioned copending application). If it is assumed the input voltage V_S varies very little over a half cycle period then the change in inductor current will ideally be given as:

$$\mathrm{A}i = \frac{1}{Ls}\int_0^{\pi}\left(V_S - V\sin\varnothing\right).d\varnothing$$

where V is either $+V_T$ or $-V_T$, the peak tank circuit voltage, depending on the switch state. Mapping the change in currents for eight combinations of the switch states into the vector space gives six values as a hexagon with the two states representing all high or all low in the centre of the hexagon. The orientation of the hexagon relates to the position of the vector of the voltage in space and the magnitude of the hexagon relates to the magnitude of the input inductor L_S. This may be chosen so that on selecting any particular switch state the resulting change in current is sufficient to track a reference current value with minimum error. Too large a value and the possible change in current will not be sufficient to follow the reference, too low a value and the change in current at each step will be excessive, causing a high level of current ripple on the input.

(2) <u>Fail Safe Power Protection</u>

The advantage of the use of high frequency transformer isolation is that, as the intermediate frequency rises the transient energy that can be transmitted between primary and secondary reduces. Thus, by stopping the primary converter circuit 104 from switching, negligible energy can then be passed from primary to secondary windings in transformer 101 and so a fail safe circuit-breaker action is provided. With known circuit-breaker systems an action must initiate the breaking of current and so there is always doubt as to whether the breaker will operate correctly. With the present invention, the breaking of current is performed by <u>preventing</u> an action, this being inherently more reliable

than initiating an action. Furthermore, it can be made "failsafe", i.e. the absence of any of a group of selected signals can inhibit the converter operation with absolute certainty.

The modes of system protection can be divided into those where damage may be caused to the substation system and those where damage may be caused to the system it is feeding. Because power transmission must have a high reliability the power feed is divided into the various sub-circuits on the secondary side of the transformer 101. The output switching circuits 105a-105d would normally control the flow of power, the use of the input switching circuit 104 to break power flow being only for catastrophic faults which would normally only occur within the converter system itself.

The manner in which the converters operate means that they should be rated to withstand the maximum current that will be present in the circuit they are supplying. This will be at a level very much higher than the rated current of the system which is based on R.M.S. current loading. The loads are all transformer coupled and when a transformer is first switched on it momentarily sees an unbalanced supply and may saturate causing a high transient unidirectional current to flow. This will normally settle within a few cycles and it is important that the supply protection function built into controller 110 is able to discriminate between this occurrence and a fault current. The function $\int i^2 dt$ rising above a permitted level is usually applied to distinguish between a transient overload and a fault current, where "i" is the current drawn from the load. Thus the following protection modes can be provided:

1. If currents drawn from the output switching circuits 105a-105d on the secondary side of the transformer 101 are above the maximum rating of the input switching circuits 104, 106 on the primary side of the transformer, the

controller 110 may cause the input switching circuits to inhibit, preventing further power transfer to the secondary side.

2. If currents from the load are above the rating of the output switching circuits 105a-105d or at a level set to be less than that for the input switching circuit 104, the controller 110 may cause the output voltage to reduce to maintain the current to within the maximum level. If this is maintained for an excessive time (e.g. > 100ms) that output switching circuit must inhibit.

3. If the result of the function $\int i^2 dt$, where "i" is the current drawn from the load, rises above a permitted level then the output switching circuits 105a-105d must inhibit. The level can be set to represent the current level for the R.M.S. rating of the load system and must be high enough that standard short term transients do not cause the system to trip.

It will be appreciated that the above described embodiments are not intended to be limiting and that other embodiments of the invention are envisaged.

CLAIMS

1. A substation for use in a power transmission and distribution network, characterised by:

a single phase isolating high frequency transformer having at least one input winding and at least one output winding;

an input solid state high frequency switching network comprising a plurality of semiconductor switching devices, the input switching network defining at least one input node for receiving an input power waveform from the transmission network and at least one output node connected to the primary winding of the transformer;

at least one output solid state high frequency switching network comprising a plurality of semiconductor switching devices, the output switching network being connected to the secondary winding of the transformer and defining at least one output node from which an output power waveform can be taken from the substation; and

control means adapted to control the operation of the switching devices of the input and output switching networks to generate the output waveform at the output node from the input waveform applied to the input node.

2. A substation according to claim 1 in which the control means is adapted to control the semiconductor switching devices in dependence upon current and/or voltage applied to the input switching network.

3. A substation according to claim 1 or claim 2, in which the control means is connected to receive power condition signals from measurement means located to sense power flowing to the input node(s), the control means being adapted to output signals to the input and output solid state switching networks thereby to control switching of the semiconductor switching devices therein in response to variations in the power condition signals.

4. A substation according to any preceding claim in which the input switching network comprises a bridge circuit having at least one input node for each phase of the input supply.

5. A substation according to any preceding claim in which the control means is adapted to:

control the semiconductor switching devices in the input switching network so that a single substantially sinusoidal waveform is generated in the primary side of the transformer; and

control the semiconductor switching devices in the output switching network to reconstruct one or more output waveforms of different phase from the waveform in the secondary side of the transformer.

6. A substation according to any preceding claim in which the control means in adapted to control the semiconductor switching devices so as to produce at least one output voltage waveform which is independent of the input voltage waveform.

7. A substation according to any preceding claim in which the semiconductor switching devices are arranged in relation to the transformer so that in the event of a failure of one or more semiconductor switching devices or of the transformer or of the control means then power is not transmitted across the transformer.

8. A substation according to any preceding claim in which the control means is adapted to control the semiconductor switching devices, at least of the input switching network, in such a way as to match the input impedance of the substation to the source impedance of the supply line.

9. A substation according to claim 8 in which the control means is adapted to modify the switching state of one or more of the switching devices thereby to control the source impedance in real time.

10. A substation according to any preceding claim in which a limiting means is provided which is adapted to reduce the maximum output voltage produced in the event that the current drain exceeds a preset level.

11. A transmission and distribution network comprising a transmission line for the transmission of electrical power from a generator, a substation in accordance with any one of claims 1 to 10 operatively connected to the transmission line, and one or more distribution lines connected to the output of the substation for onward supply of power to a load.

12. A network according to claim 11 in which the load comprises a second transmission line adapted to transmit alternating voltage from a generator, and the control means is adapted to control the switching of the switching devices to generate an output waveform for supply to the second network which is in phase with the phase of the voltage on the second network.

13. The network of claim 11 or claim 12 in which the substation comprises two transformers and associated input and output switching networks connected in parallel between the supply line and the output load.

14. The network of claim 14, 15 or 16 in which a circuit breaker and an isolator are provided upstream of the substation and an isolator is provided downstream of the substation.

AMENDED CLAIMS

[received by the International Bureau on 26 September 2001 (26.09.01); original claims 1-14 replaced by amended claims 1-13 (3 pages)]

1. A substation for use in a power transmission and distribution network, characterised by:

a single phase isolating high frequency transformer having at least one input winding and at least one output winding;

an input solid state high frequency switching network comprising a plurality of semiconductor switching devices, the input switching network defining at least one input node for receiving an input power waveform from the transmission network and at least one output node connected to the primary winding of the transformer;

at least one output solid state high frequency switching network comprising a plurality of semiconductor switching devices, the output switching network being connected to the secondary winding of the transformer and defining at least one output node from which an output power waveform can be taken from the substation; and

control means adapted to control the operation of the switching devices of the input and output switching networks to generate the output waveform at the output node from the input waveform applied to the input node, the control means being connected to receive power condition signals from measurement means located to sense power flowing to the input node(s), the control means being adapted to output signals to the input and output solid state switching networks thereby to control switching of the semiconductor switching devices therein in response to variations in the power condition signals.

2. A substation according to claim 1 in which the control means is adapted to control the semiconductor switching devices in dependence upon current and/or voltage applied to the input switching network.

3. A substation according to any preceding claim in which the input switching network comprises a bridge circuit having at least one input node for each phase of the input supply.

4. A substation according to any preceding claim in which the control means is adapted to:

control the semiconductor switching devices in the input switching network so that a single substantially sinusoidal waveform is generated in the primary side of the transformer; and

control the semiconductor switching devices in the output switching network to reconstruct one or more output waveforms of different phase from the waveform in the secondary side of the transformer.

5. A substation according to any preceding claim in which the control means in adapted to control the semiconductor switching devices so as to produce at least one output voltage waveform which is independent of the input voltage waveform.

6. A substation according to any preceding claim in which the semiconductor switching devices are arranged in relation to the transformer so that in the event of a failure of one or more semiconductor switching devices or of the transformer or of the control means then power is not transmitted across the transformer.

7. A substation according to any preceding claim in which the control means is adapted to control the semiconductor switching devices, at least of the input switching network, in such a way as to match the input impedance of the substation to the source impedance of the supply line.

8. A substation according to claim 7 in which the control means is adapted to modify the switching state of one or more of the switching devices thereby to control the source impedance in real time.

9. A substation according to any preceding claim in which a limiting means is provided which is adapted to reduce the maximum output voltage produced in the event that the current drain exceeds a preset level.

10. A transmission and distribution network comprising a transmission line for the transmission of electrical power from a generator, a substation in accordance with any one of claims 1 to 10 operatively connected to the transmission line, and one or more distribution lines connected to the output of the substation for onward supply of power to a load.

11. A network according to claim 10 in which the load comprises a second transmission line adapted to transmit alternating voltage from a generator, and the control means is adapted to control the switching of the switching devices to generate an output waveform for supply to the second network which is in phase with the phase of the voltage on the second network.

12. The network of claim 10 or claim 11 in which the substation comprises two transformers and associated input and output switching networks connected in parallel between the supply line and the output load.

13. The network of claim 10, 11 or 12 in which a circuit breaker and an isolator are provided upstream of the substation and an isolator is provided downstream of the substation.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference P/70038/SF	**FOR FURTHER ACTION** see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
International application No. PCT/GB 01/ 01182	International filing date *(day/month/year)* 19/03/2001	(Earliest) Priority Date *(day/month/year)* 18/03/2000
Applicant ALSTOM et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

☒ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language,** the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   ☐ the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   ☐ contained in the international application in written form.
   ☐ filed together with the international application in computer readable form.
   ☐ furnished subsequently to this Authority in written form.
   ☐ furnished subsequently to this Authority in computer readble form.
   ☐ the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   ☐ the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. ☐ **Certain claims were found unsearchable** (See Box I).

3. ☐ **Unity of invention is lacking** (see Box II).

4. With regard to the **title,**

   ☒ the text is approved as submitted by the applicant.
   ☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract,**

   ☒ the text is approved as submitted by the applicant.
   ☐ the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 2

   ☐ as suggested by the applicant.
   ☒ because the applicant failed to suggest a figure.
   ☐ because this figure better characterizes the invention.

   ☐ None of the figures.

INTERNATIONAL SEARCH REPORT

Int[illegible]onal Application No
P[illegible]B 01/01182

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H02M5/22

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H02M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 109 185 A (BALL NEWTON E) 28 April 1992 (1992-04-28) column 36, line 10-29 figures A3B,4,22 claim 1 ---	1,2,4-6, 10-14
A	ROOIJ DE M A ET AL: "A NOVEL UNITY POWER FACTOR LOW-EMI UNINTERRUPTIBLE POWER SUPPLY" IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS,US,IEEE INC. NEW YORK, vol. 34, no. 4, July 1998 (1998-07), pages 870-876, XP000848029 ISSN: 0093-9994 page 870, column 1, paragraph 3 figures 1-3 --- -/--	1-14

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 July 2001	27/07/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	MARANNINO, M

Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 018 058 A (IONESCU ADRIAN F ET AL) 21 May 1991 (1991-05-21) abstract figure 1 ---	1-14
A	DE 299 10 979 U (SIEMENS AG) 9 September 1999 (1999-09-09) abstract column 2, line 14 - line 36 figure 1 -----	1-14

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 01/01182

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5109185 A	28-04-1992	NONE	
US 5018058 A	21-05-1991	WO 9201329 A	23-01-1992
DE 29910979 U	09-09-1999	NONE	

10/031254

PATENT COOPERATION TREATY

REC'D 02 SEP 2002

WIPO PCT

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference P/70038.WOP/SF	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/GB01/01182	International filing date *(day/month/year)* 19/03/2001	Priority date *(day/month/year)* 18/03/2000
International Patent Classification (IPC) or national classification and IPC H02M5/22		
Applicant ALSTOM et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 7 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 3 sheets.

3. This report contains indications relating to the following items:

   I ☒ Basis of the report
   II ☐ Priority
   III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   IV ☐ Lack of unity of invention
   V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   VI ☐ Certain documents cited
   VII ☐ Certain defects in the international application
   VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
11/10/2001	30.08.2002
Name and mailing address of the international preliminary examining authority: European Patent Office - P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk - Pays Bas Tel. +31 70 340 - 2040 Tx: 31 651 epo nl Fax: +31 70 340 - 3016	Authorized officer Marannino, E. Telephone No. +31 70 340 3906

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB01/01182

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:

Description, pages:

1-19 as originally filed

Claims, No.:

1-15 as received on 15/07/2002 with letter of 12/07/2002

Drawings, sheets:

1/3-3/3 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language: , which is:

- ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB01/01182

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-13
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-13
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-13
	No:	Claims	

2. Citations and explanations
   see separate sheet

Re Item V

Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Reference is made to the following document:

D1: US-A-5 109 185 (BALL NEWTON E) 28 April 1992 (1992-04-28)

The present international application relates to power transmission and distribution network

Novelty

1.1 Back ground

Document D1 (fig. 22, column 24, lines 7-26), which is the closest prior art for the application, discloses a substation (rural power connection) for use in a power transmission and distribution network comprising:

(i) a single phase isolating high frequency transformer having at least one input winding and at least one output winding;

(ii) an input solid state high frequency switching network (P1, P3 on the primary side of the transformer) comprising a plurality of semiconductor switching devices (for example S1-S4 of fig. 4), the input switching network defining at least one input node for receiving an input power waveform from the transmission network and at least an output node connected to primary winding of the transformer;

(iii) at least one solid state high frequency switching network (P1, P3, P4 on the secondary side of the transformer) comprising a plurality of semiconductor switching devices (for example S17-S20 of fig. 7), the output switching network being

connected to secondary winding of the transformer and defining at least one output node from which an output power waveform can be taken from the substation;

(iv) control means ("control panel") adapted to control the operation of the switching devices of the input and output switching network to generate the output waveform at the output node from the input waveform applied to the input node;

1.2 Differences over prior art D1

New claim 1, as amended with letter of 12/07/2001 differs from D1 in that the substation comprises:

1) measurement means located to sense power flowing to the input nodes,

2) the control means **are** connected to receive power condition signals from said measurement means and **are** adapted to output signals to the input and the output solid state switching network thereby to control switching of the semiconductor switching devices therein in response to variations in the power condition signals.

3) **means for inhibiting switching of the input or output switching networks if the current taken from an output node exceeds a predetermined level.**

Therefore claim 1 is new and fulfils the requirements of Article 33(2) PCT.

<u>**Inventive step**</u>

1. The first two features of the invention with respect to prior art D1 solve the problem of reactive power (see description page 6, lines 21-24).

1.1 This problem is already mentioned in prior art D1. Document D1 (fig. 16, column 47 lines 8-34) shows a UPS system which works with a unitary power factor. It is clear since there is not additional static var compensator that such power factor compensation is achieved by switching the input port on the basis of measurement

of input power.

1.2 The person skilled in the art using the rural network of fig. 22 as a power factor corrector UPS as taught in fig.16 would arrive to the subject matter of the amended claim 1 without using an inventive activity.

2. Although the first two features are not inventive and trivial for the man skilled in the art, the third feature is not an evident feature of the particular substation of D1.

2.1 The problem solved by this **means for inhibiting switching of the input or output switching networks if the current taken from an output node exceeds a predetermined level** is:
protecting the substation from exceeding current.

2.2 In solving the problem of protecting the person skilled in the art would probaly use the known technique of electromecanical circuit breakers and would not arrive at the solution of the application.

Therefore claim 1 fulfills the requirement of Article 33(3) about inventive step.

The remaining dependent claims are also inventive (Article 33(3)).

Industrial applicability

As already mentioned the substation of claim 1 finds an application in power transmission and distribution network, therefore the industrial applicability of claim 1 is beyond any doubt (Article 33(4) PCT).

Independent claim 1 thus meets the requirements of Articles 33(2), 33(3), 33(4) PCT.

Since the remaining claims are dependent on claim 1, they also meet the requirements of PCT (Article 33(2), 33(3), 33(4) PCT).

Minor objections

1. Contrary to the requirements of Rule 5.1(a)(ii) PCT, the relevant background art disclosed in the document D1 is not mentioned in the description, nor is this document identified therein.

2. The description (page 4, lines 1-15) is not in conformity with the latest version of claim 1 as required by Rule 5.1(a)(iii) PCT, because all the features of claim 1 should be present in the description.

CLAIMS

1. A substation for use in a power transmission and distribution network, comprising:

a single phase isolating high frequency transformer having at least one input winding and at least one output winding;

an input solid state high frequency switching network comprising a plurality of semiconductor switching devices, the input switching network defining at least one input node for receiving an input power waveform from the transmission network and at least one output node connected to the primary winding of the transformer;

at least one output solid state high frequency switching network comprising a plurality of semiconductor switching devices, the output switching network being connected to the secondary winding of the transformer and defining at least one output node from which an output power waveform can be taken from the substation; and

control means adapted to control the operation of the switching devices of the input and output switching networks to generate the output waveform at the output node from the input waveform applied to the input node, characterised by:

the control means being connected to receive power condition signals from measurement means located to sense power flowing to the input node(s), the control means being adapted to output signals to the input and output solid state switching networks thereby to control switching of the semiconductor switching devices therein in response to variations in the power condition signals, and

means for inhibiting switching of the input or output switching networks if the current taken from an output node exceeds a predetermined level.

2. A substation according to claim 1, in which the means for inhibiting switching comprises the control means.

3. A substation according to claim 2, in which the predetermined current level is the maximum current rating of the input switching network.

4. A substation according to claim 2 or claim 3, in which the predetermined current level is the maximum rating of the output switching network or a level less than the maximum current rating of the input switching network and the control means is adapted to reduce the output voltage to maintain the output current within the predetermined current level for a predetermined time before preventing switching.

5. A substation according to any one of claims 2 to 4, in which the predetermined current level is the R.M.S. rating of a load system connected to the output node, as represented by the function $\int i^2 dt$, where "i" is the current drawn from the load.

6. A substation according to any preceding claim in which the input switching network comprises a bridge circuit having at least one input node for each phase of the input supply.

7. A substation according to any preceding claim in which the control means is adapted to:

control the semiconductor switching devices in the input switching network so that a single substantially sinusoidal waveform is generated in the primary side of the transformer; and

control the semiconductor switching devices in the output switching network to reconstruct one or more output waveforms of different phase from the waveform in the secondary side of the transformer.

8. A substation according to any preceding claim in which the control means is adapted to control the semiconductor switching devices so as to produce at least one output voltage waveform which is independent of the input voltage waveform.

9. A substation according to any preceding claim in which the semiconductor switching devices are arranged in relation to the transformer so that in the event of a failure of one or more semiconductor switching devices or

of the transformer or of the control means then power is not transmitted across the transformer.

10. A substation according to any preceding claim in which the control means is adapted to control the semiconductor switching devices, at least of the input switching network, in such a way as to match the input impedance of the substation to the source impedance of the supply line.

11. A substation according to claim 10 in which the control means is adapted to modify the switching state of one or more of the switching devices thereby to control the source impedance in real time.

12. A transmission and distribution network comprising a transmission line for the transmission of electrical power from a generator, a substation in accordance with any one of claims 1 to 11 operatively connected to the transmission line, and one or more distribution lines connected to the output of the substation for onward supply of power to a load.

13. A network according to claim 12 in which the load comprises a second transmission line adapted to transmit alternating voltage from a generator, and the control means is adapted to control the switching of the switching devices to generate an output waveform for supply to the second transmission line which is in phase with the phase of the voltage on the second transmission line.

14. The network of claim 12 or claim 13 in which the substation comprises two transformers and associated input and output switching networks connected in parallel between the supply line and the output load.

15. The network of any one of claims 12 to 14, in which a circuit breaker and an isolator are provided upstream of the substation and an isolator is provided downstream of the substation.

DETAILED ACTION

Drawings

1. The drawings are objected to because the boxes (E, 104, 105, 106, 110) in figure 2 should be labeled with worded descriptive labels. A proposed drawing correction or corrected drawings are required in reply to the Office action to avoid abandonment of the application. The objection to the drawings will not be held in abeyance.

2. The drawings are objected to under 37 CFR 1.83(a). The drawings must show every feature of the invention specified in the claims. Therefore, the at least one output solid state switching network comprising a plurality of semiconductor switching devices must be shown or the feature(s) canceled from the claim(s). No new matter should be entered.

A proposed drawing correction or corrected drawings are required in reply to the Office action to avoid abandonment of the application. The objection to the drawings will not be held in abeyance.

The applicant has supplied a figure for the switching converters 104 and 106 but not for 105.

Specification

The following guidelines illustrate the preferred layout for the specification of a utility application. These guidelines are suggested for the applicant's use.

Arrangement of the Specification

As provided in 37 CFR 1.77(b), the specification of a utility application should include the following sections in order. Each of the lettered items should appear in upper case, without underlining or bold type, as a section heading. If no text follows the section heading, the phrase "Not Applicable" should follow the section heading:

(a) TITLE OF THE INVENTION.
(b) CROSS-REFERENCE TO RELATED APPLICATIONS.
(c) STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT.
(d) INCORPORATION-BY-REFERENCE OF MATERIAL SUBMITTED ON A COMPACT DISC (See 37 CFR 1.52(e)(5) and MPEP 608.05. Computer program listings (37 CFR 1.96(c)), "Sequence Listings" (37 CFR 1.821(c)), and tables having more than 50 pages of text are permitted to be submitted on compact discs.) or
REFERENCE TO A "MICROFICHE APPENDIX" (See MPEP § 608.05(a). "Microfiche Appendices" were accepted by the Office until March 1, 2001.)
(e) BACKGROUND OF THE INVENTION.
(1) Field of the Invention.
(2) Description of Related Art including information disclosed under 37 CFR 1.97 and 1.98.
(f) BRIEF SUMMARY OF THE INVENTION.
(g) BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S).
(h) DETAILED DESCRIPTION OF THE INVENTION.
(i) CLAIM OR CLAIMS (commencing on a separate sheet).
(j) ABSTRACT OF THE DISCLOSURE (commencing on a separate sheet).
(k) SEQUENCE LISTING (See MPEP § 2424 and 37 CFR 1.821-1.825. A "Sequence Listing" is required on paper if the application discloses a nucleotide or amino acid sequence as defined in 37 CFR 1.821(a) and if the required "Sequence Listing" is not submitted as an electronic document on compact disc).

The specification requires headings.

3. The specification has not been checked to the extent necessary to determine the presence of all possible minor errors. Applicant's cooperation is requested in correcting any errors of which applicant may become aware in the specification.

4. The title of the invention is not descriptive. A new title is required that is clearly indicative of the invention to which the claims are directed.